DEVELOPMENT OF PLUG-IN AIR POWERED FOUR WHEELS MOTORCYCLE DRIVETRAIN CONTROL UNIT

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ABSTRACT

This thesis is related to the development of plug-in air powered four wheel motorcycles drive train system that transfers rotational energy from power train to the driving wheel. The objective of this thesis is to develop an air hybrid drivetrain unit and control the power and torque from the powertrain to the driving wheel by using sequential manual transmission. This thesis describes the process of developing sequential shift-by-wire system to make gear shifting for easier for 4 wheel motorcycle. The controller used in this project was 18F PIC 4550 microprocessor. The system programming performed using FLOWCODE version 4.0. 2 units of electromechanical linear actuator were used in this project as an actuator for gear shifting on a manual transmission. Chain drives were selected as power transfer linkage from air hybrid engine to the driving wheel with under drive configuration. Besides the development of shift-by-wire system, the torque on the driving wheel also had been calculated and analysed. In additional, the maximum speed that can be achieved by four wheel motorcycles was also calculated**.**

ABSTRAK

Tesis ni berkaitan dengan pembangunan sistem pacuan yang memindahkan tenaga putaran ke roda pacuan untuk “plug-in hybrid air powered” motosikal empat roda. Objectif tesis ini ialah untuk membangunkan pacaun “ air hybrid” and mengawal kuasa and tork daripada janakuasa kepada roda paduan mengunakan transmisi manual berturutan. Tesis in menjelaskan proses pembangunan system “sequential shift-by-wire” Untuk menjadikan proses pertukaran gear lebih senang bagi motosikial beroda empat. PIC 18F4550 mikropemproses telah digunakan sebagai sistem kawalan utama untuk sistem “sequential shift-by-wire”. Pengaturcaraan untuk sistem kawalan mengunakan perisisan FLOWCODE versi 4.0. 2 unit penggerak lurus telah digunakan sebagai penggerak untuk pertukaran gear pada transmisi manual. Paduan rantai teleh dipilih untuk menghubungkan kausa dari enjin“ air hybrid” kepada roda pacuan dengan konfigurasi “ under drive”. Selain daripada pembangunan sistem “ shift-by-wire”, tork yang ada pada roda pacuan juga dikira dan dianalisis. Sebagai tambahan, kelajuan maksimum yang boleh dicapai oleh motosikal empat roda juga telah dikira.

TABLE OF CONTENT

APPENDICES

LIST OF TABLES

LIST OF FIGURE

LIST OF SYMBOLS

L	length
m	mass
r	radius
a	acceleration
F	force
ω	Angular velocity
T	torque
v	velocity

CHAPTER 1

INTRODUCTION

1.3 BACKGROUND STUDY

Nowadays, there are many research that had been done to develop a vehicle that can run on the alternative fuel like hydrogen fuel cell, bio-fuel, electric propulsion vehicle, hybrid system and most recently is a vehicle that totally runs from compressed air. But most of this development of only focuses on car drivetrain and not for motorcycles.

In the early years of development air-hybrid vehicle, the drivetrain system is design base of the passage vehicle platform. It was developed by a French engineer Guy Négre in Luxembourg, French. The compress air vehicle design by the Guy Négre use continuously variable transmission to change the torque constant torque from air hybrid engine to the driving wheels. Over the time, the design of the drivetrain system by Guy Négre was refined and use in many Motor Development International vehicle models. But until now, there doesn't have any development of drivetrain system that can be used in motorcycle to transmit torque and power to driving wheel effectively.

Although there are already 52 patents have been registered for air hybrid engine since 1979(Singh & Onkar), but there are not any recent development of a drivetrain system that suitable use in motorcycles. The development of an air hybrid drivetrain system is very important to the ASEAN country where most of its population using motorcycles as main transportation (World Health Organization, 2009).

1.4 PROBLEM STATEMENT

The development of the motorcycles drivetrain system is surprisingly fast with the introduction of new technology by motorcycle manufacture. Normally the type of transmission that had used for the motorcycle transmission is a manual sequential transmission and continuous variable transmission (CVT). Both types of transmission are chosen to be used in motorcycles because it has few advantages like light weight and compact. But for hybrid engine, manual transmission is preferable because it has the ability to the handle power and torque from the hybrid engine compare to continuous variable transmission.

By using manual transmission in drivetrain system also will give the driver full control of the motorcycle performance. Manual transmission can increase the fuel efficiency of the motorcycles because it has high mechanical efficiency when transfer the engine power to the driving wheel with minimum losses of energy (Manish Kulkarni, Taehyun Shim, Yi Zhang,2007). But it has a one drawback with the 'H' shift patter which is taking too much of space in the confines of the motorcycle frame.

To overcome this drawback, manual transmission with sequential ability for shifting gear is required to be developed. By developing these type of transmission can reduce the size of motorcycle chassis to more compact due to it can eliminate the use of 'H' patter in gear shifting. It also can reduce the complexity of gear shift patter compare to manual transmission hence give driver ability to select the desired gear without letting go of the handlebars.

1.5 OBJECTIVE

The main objectives of this project are:

a. To develop of air hybrid drivetrain unit.
b. To control the power and torque from powertrain to driving wheel by using sequential manual transmission.

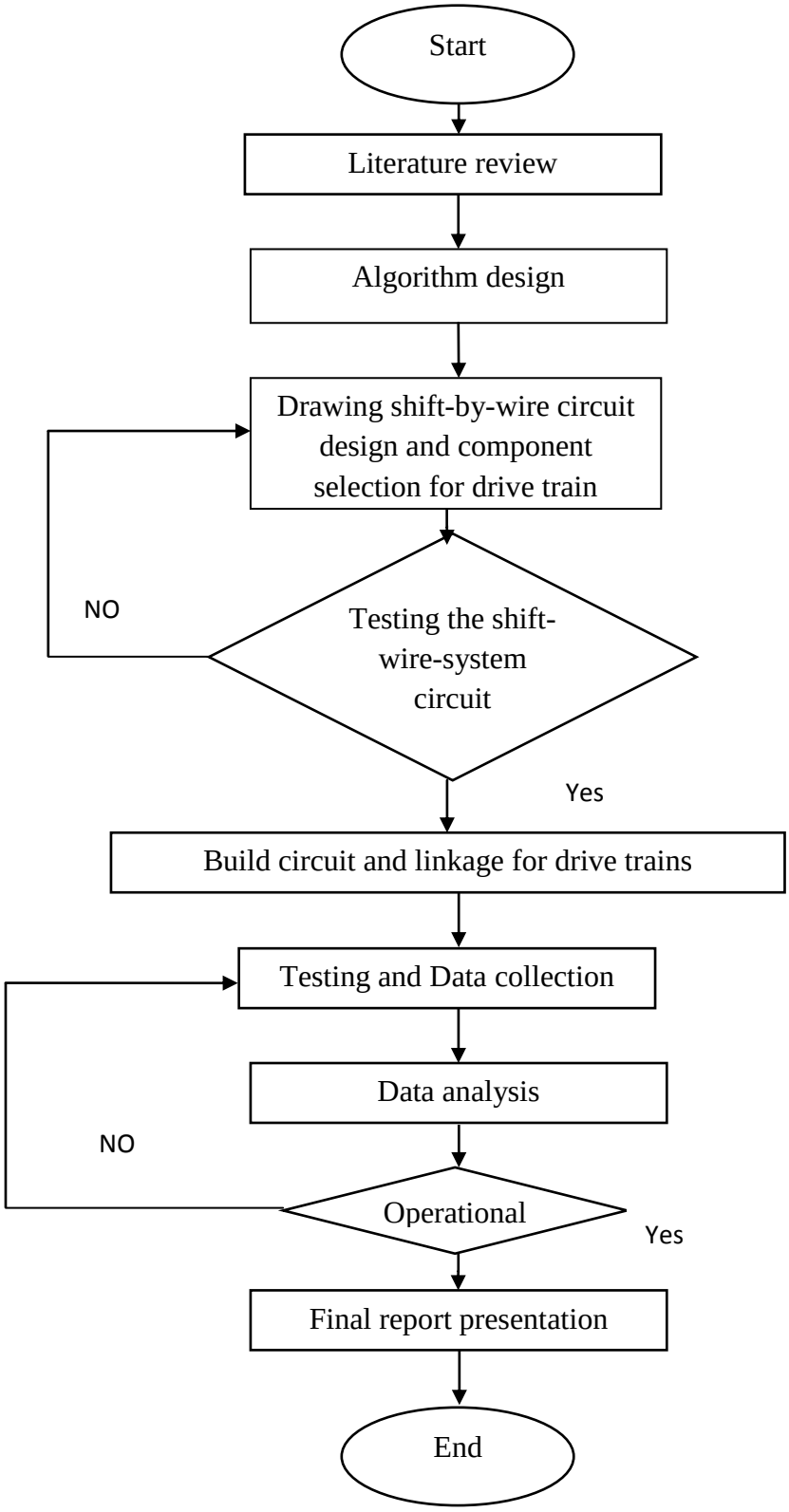
1.6 WORK SCOPES

a. Development of single power transfer linkage unit.
b. Integration between powertrain, drivetrain, power transfer unit and driving wheel.
c. Design a shift by wire sequential manual transmission system to control the gear ratio.
d. Prototype model working analysis.
e. Final report preparation .

1.5 HYPOTHESIS

A manual transmission is changed into sequential manual transmission for use in 4 wheel motorcycle's development. This sequential action is controlled by the control module. By the end of the development, 4 wheel motorcycles can eliminate a drawback of normal H patter manual transmission which is taking a lot of space in the confines of 4 wheel motorcycle frames and give the driver ability to select the desired gear without letting go the handlebars.

1.6 FLOWCHART



1.7 GANTT CHART

Please refer to appendix A1 for reference

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The vehicle drive train system is important because it functions to transfer rotational energy from power train to the wheel. The drive train system mechanical efficiency depends on how the system is designed. Typical vehicle drive train system will have components like clutch, transmission box, drive shaft or chain drive, and wheel, which are controlled by the driveline management system (Magnus, 1996).

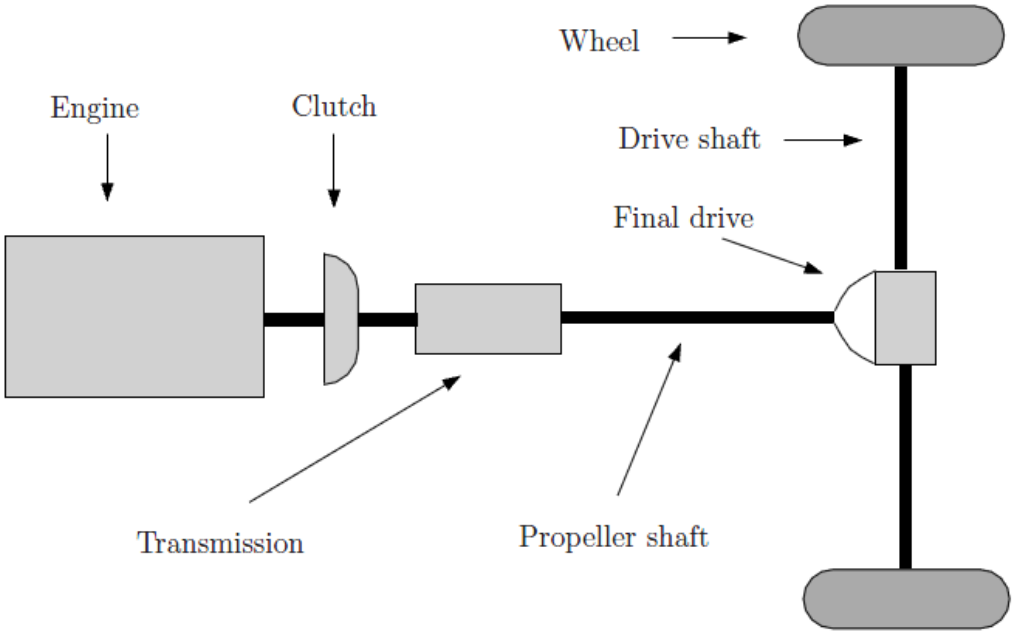


Figure 2.1: Typical vehicle drive train for rear wheel drive

Source: Magnus (1996)

A good configuration of the drive train system needs to customize with the chassis design to ensure optimum performances hence reduces energy consumption and pollutant gaseous emissions. (Sérgio, Jorge, and Paulo,2005).

2.2 POWERTRAIN SYSTEM

Powertrain is the main component in any modern vehicle even for the motorcycles. Most of the motorcycles on the road today use an internal combustion engine as it Powertrain. The internal combustion engine converts chemical energy from the fossil fuel via combustion to the kinetic energy to move the motorcycles (Jack, 2011).

2.2.1 EA71 Engine Model

One of the internal combustion engines that developed in 1970s is EA71 manufacture by Fuji Heavy Industries under 'Subaru' brand. EA71 engine by Subaru is unique due to most internal combustion engine that have 4 piston is using inline engine configuration, but EA71 engine is using flat-4 design or also know as boxer engine. The EA71 engine was used in Subaru Leone or Brat manufacture from year 1976 to 1994 (www.subaru.com, retrieved on 8 November 2012).

The EA71 engine is gasoline internal combustion engines that have 4 cylinders and 2 valves per cylinder. Each cylinder has 3.62 x 2.36 in of bore and stroke setting than make total displacement is 1595cc. For ignition system, EA71 engine uses distributor with firing order 1-3-2-4. EA71engine use overhead valve (OHV) valvetrain technology by using push rod to actuate the rocker arm to actuate the valves. Figure 2.1 shows the picture of EA71 engine.

Figure 2.2: EA71 engine

Source: www.allenginelist.com, retrieved 8 November 2012

2.2.2 Engine specification

EA71 engine can produce maximum output at 87 brake horse power at engine speed of 5600rpm and maximum torque is 120Nm of 3600 RPM. The brake effective pressure for EA71 engine is about 945.4 KPa and it can reach maximum top speed 150 Km/h. The EA71 engine specification is available in Table 2.1.

Table 2.1: EA71 Engine specification

Specs Item	Specification
Engine Type	EA71 Subaru Engine
Engine Manufacture	Subaru
Engine Variants	EA Engine Family
Displacement	1595cc
Transmission Type	5 Speed Manual Transmission (TM752RX3AA)
Compression Ratio	9 :1
Bore and Stroke (mm)	92mm x 60mm
Valve Per Cylinder	2 Valve
Valve System	Overhead Valve
Fuel System	Carburetor

Fuel Type	Gasoline
Maximum Engine Speed	5800 RPM
Horsepower	88.2 PS (87 bhp) (64.9 kW) at 5600 RPM
Torque	120Nm at 3600 RPM
Engine coolant	Water
Aspiration	Normal
Engine Installation	Front longitudinal
Maximum Top speed	150 Km/h
Brake Effective Pressure	945.4 KPa

Source: www.allenginelist.com, retrieved on 8 November 2012

2.3 GEAR TRANSMISSION SYSTEM

2.3.1 Development of Transmission System

In year 1894, three speed manual transmissions were invented by 2 French investors Louis-Rene Panhard and Emile Levassor. In early year of development of manual transmission, Panhanrd and Levassor use chain drive on their transmission. In year 1898, auto maker Louis Renault improves Panhanrd and Levassor transmission design by substituting a drive shaft for the drive shaft and added differential axle in the rear wheels to improve the performance of the manual transmission system (Yates, 2009).

In the beginning of the 20th century, most of the car manufactures using non-synchronized manual transmission based on the Renault design as a standard for all vehicles By the year 1928, Cadillac introduced the synchronized manual transmission. The synchronized manual transmission significantly reduces gear grinding and made shifting easier and smoother.

In year 1938, General Motor introduced a clutchless automatic transmission, Hydra-Matic which is used a torque converter in state of dry clutch and planetary gear

set. Planetary gear uses to replace conversional gear set (Jefferson, McFarland, and Coy, 2008).

The evolution of transmission continued with the development of dual clutch transmission and the sequential manual transmission with the introduction of microprocessor in the 1980s. In year 1981, dual clutch transmission was introduced with prototypes built into the Ford Fiesta Mk1, Ford Ranger & Peugeot 205. Initially dual clutch transmission was designed for use in high performance car like the Porsche 911 and Audi Sport Quattro, until in the year 2003 where it uses in first road car Volkswagen golf Mk4 (www.volkwagen.com, retrieved on 8 November 2012)

2.3.2 Manual Transmission

. Manual transmission is a type of transmissions that give driver ability to choose it desire any forward gear ratio that are available. Manual transmission uses the dry clutch system to connect and disconnect power from the crankshaft, hence control the power flows from engine to transmission. This clutch engagement is controlled by the user using lever can cable system.

Dry clutches transmit torque from engine to manual transmission by use friction phenomenon that was generated when the friction pad mounted on the two sides clutch disk against the rotation of the flywheel and pressure pad. The maximum torque that can transmit by dry clutch is when the clutch is fully close (Francesco, Luigi, Adolfo, and, Maurizio 2008).

Figure 2.3: Manual Transmissions

2.3.3 Advantage of the Manual Transmission Compare to Automatic transmission

The transmission efficiency is becoming a very significant factor in the overall vehicle efficiency due to the increasing stringent emission target and the limits that had been achieved by an internal combustion engine (ICE). During the operation, transmission ratio is selected by the user in the passenger cabin for manual transmission or by a transmission control unit, as in stepper automatic transmission (AT) or continuous variable transmission (CVT). This transmission ratio is select depend on the vehicle driving conditions.

Manual transmissions have the advantage of having high mechanical efficiency, with the most of the lost come from the lubricant churning which is an undesirable friction that occurs between fluids. Automatic transmission l have lower mechanical efficiency compare to manual transmission because automatic transmission needs to constantly run the hydraulic pump to provide the power for clutch actuation, cooling, gear, and bearing lubrication. The Hydraulic pump is directly driven by the output from the internal combustion engine, and is rated to provide the required oil pressure and flow rate to enable clutch actuation (Andrew, Keith, Richard, and David, 2007).

2.3.4 Motorcycle Transmission

There are two types of transmission that mostly use in motorcycles to transfer engine rotational energy to the driving wheel; sequential manual transmission and continuous variable transmission. The sequential manual transmission mostly will be use in modern motorcycles except for scooter and ATV where they used continuously variable transmission as its transmission box (Abdo, 2002).

The sequential manual transmission, the gears only can be selected in order and direct access to specific gear is not allowed. On the sequential manual transmission gearbox, the gear shift lever operates a ratchet mechanism that converts the back and forth movement of the shift lever into a rotary motion. This rotary action will turn a selector drum which has three or four tracks machined around its circumference. Running on the tracks is the selector forks, either directly, or via selector rods. These

tracks deviate around the circumference and as the drum rotates, the selector forks running on the tracks are moved to select the required gear (Valentina, 2010).

While for continuous variable transmission, it will consist of a drive pulley which is attached to the engine crankshaft and a driven pulley that's attached to a shaft which may also incorporate a centrifugal clutch. Driving and driven pulley are connected by a drive belt. As engine speed increases, centrifugal force pushes the weight rollers outward. This force pushes the movable face toward the fixed face, which in turn pushes the drive belt upward toward the top of the drive pulley. This reduces the drive ratio by forcing the drive belt to ride on a pulley of larger diameter. As the engine speed decreases, the belt is pulled back into the drive pulley, which increases the drive ratio by allowing the belt to ride on a pulley of smaller diameter (Abdo, 2002).

2.4 GEAR SHIFT AND FUEL CONSUMPTION

Based on the transmission gear ratio and engine data, it is important to get the harmonic gear shift position to optimize the vehicle performance and fuel consumption. Based on the analysis of the relation between driving behaviors and fuel consumption prove factor like gear selection, driving speed and acceleration or deceleration will give largest influence on the fuel consumption. These researches also show, the fuel consumption at the same average driving speed can be increased up to 20% only due to differences in the manner of gear shifting. The effect of the gear selection at the same speed and total fuel consumption can observe in Figure 2.3.

When taking fuel consumption in 5^{th} gear at speed of 50km/h as a branch mark. At 50km/h, the results show that 3^{rd} gear consume more fuel compare to when the drive's selected 5^{th} gear when the speed is 50km/h. This can be concluded that significant saving in fuel consumption can be achieved by select suitable gear set which has both large economic and environmental significance (Ivan, Goran, Gradimir, Slobodan, and Vladimir, 2010).